Demographic aspects of the COVID-19 pandemic in Italy, Spain, Germany, and South Korea

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ABSTRACT The COVID-19 Pandemic has become an object of many studies and research papers. Although knowledge of the demographic features of the illness could be important for targeting the prevention, or treatment and evaluation, of the situation, demographic research was rather limited in the initial phases of the pandemic. This paper aims to present the basic demographic aspects of the illness (age-specific and crude rates) and to estimate the effects of age-specific rates and age structures on the overall, generally used measures. For this analysis, Italy, Spain, Germany, and South Korea were selected. The most important differences among these countries were traced based on the age-specific measures and age structures. The demographic method of decomposition was used for the most crucial part of the analysis. It was proven that the level of incidence (particularly at higher ages) is noticeably significant regarding the observed differences. The effects of population age structure and the level of fatality are somewhat weaker.

KEY WORDS COVID-19 – demography – age structure – age-specific rates – fatality – lethality – incidence – Italy – Spain – Germany – South Korea – decomposition

HULÍKOVÁ TESÁRKOVÁ, K. (2020): Demographic aspects of the COVID-19 pandemic in Italy, Spain, Germany, and South Korea. Geografie, 125, 2, 139–170.
https://doi.org/10.37040/geografie2020125020139
Received April 2020, accepted May 2020.

1. Introduction

Currently, the world stands in a completely new epidemiological situation. Of course, there were more epidemics or pandemics in the past, but this could be considered as the first one which is tracked and researched almost instantaneously via the internet. The COVID-19 pandemic (declared on March 11, 2020, by the World Health Organization, hereinafter as WHO) affects not only the individual lives, societies, cities, economies, and political structures of the world, but also the research of many fields of study. The novel coronavirus-infected pneumonia (originally labeled as NCIP) currently known as COVID-19 disease is being studied from many directions throughout the world (Xu, Gutierrez, Mekaru et al. 2020; Li et al. 2020; European Centre for Disease Prevention and Control 2020a, some other authors are cited below). The massive research of this topic had already started in January 2020, when studies based on the first groups of persons with confirmed illness were published, e.g. Li et al. (2020) studied the first 425 of them in Wuhan, Hubei province in China, where the disease started to spread in December 2019.

Logically, the first research was oriented above all on biological, medical, epidemiological, or virologic factors and particular medical case studies. Mostly the goal of such studies was the estimation of the most important epidemiologic features (e.g. epidemiologic doubling time or reproductive number) or tracing the source of the infection. Demographic approaches were usually limited only to the calculation of basic indicators or characteristics – average or median age, sex ratio, age structure, etc. (e.g. Li et al. 2020, Wang et al. 2020, Chen et al. 2020, etc.).

Mostly from March 2020, the attention was focused more on the development in Europe, because the situation seemed to be more or less stabilized in Asia (above all in China, South Korea, etc.). At the same time, in Europe, the number of cases started to increase rapidly. The development of the illness observed e.g. in Italy at the end of February/beginning of March started to be compared to the situation in Wuhan or province of Hubei a month before (European Centre for Disease Prevention and Control 2020a; Dzúrová, Jarolímek 2020). On the other hand, differences started to be found, e.g. different age structures of victims or different levels of fatality rates, which were much higher in Italy than in China (Rubino et al. 2020, Lippi et al. 2020). In both countries, however, the higher risk of death or severe symptoms of the illness was confirmed for older age groups (European Centre for Disease Prevention and Control 2020a). From this, it is clear, that age (the most important demographic factor) plays a significant role in the evaluation of the illness, its causes, and its consequences.

As the number of confirmed cases as well as registered deaths increased and the information and data related to the illness became more available, other aspects started to be studied more often. This could significantly contribute to the fight with the illness, the pandemics subsequent elimination, limitation of its consequences (deaths, economic or social impacts), targeting of prevention, etc. (e.g. Dzúrová, Jarolímek 2020; Mogi, Spijker 2020).

Among the many new points of view, there was, for example, the social epidemiologic or geographic analysis (Dzúrová, Jarolímek 2020, who focused on the Czech population and outlook on the development of the infection in the Czech population), analysis of cultural, economic, or demographic differences among selected countries (Mogi, Spijker 2020) or the first studies of epidemiologic as well as demographic patterns related to the illness (age structure of the population with confirmed illness, registered victims, rates of incidence, prevalence, mortality or fatality, etc.) in various populations (Mogi, Spijker 2020; European Centre for Disease Prevention and Control 2020a).

The rapidly growing database of the registered cases of illness, as well as deaths, offers still bigger possibilities of social epidemiologic or demographic studies. Epidemics such as the current one could be strongly affected and conditioned by the demographic characteristics of the population which should be considered also in other types of analyses. Using data for four selected populations this paper presents the most important demographic features of the state of the pandemic and their potential contribution to observed differences among the countries.

There are two main goals of the paper. The first of them is to illustrate the observed differences in fatality rates (usually defined as the proportion of deaths from the confirmed cases), cumulative incidence (total number of confirmed cases), or lethality (registered deaths from the studied illness) among the countries when all the numbers are adjusted for the population size.[1] The analysis is focused on age differences in the studied processes.

The second goal is to estimate the effects of the particular components of summary measures on their observed differences among countries. Those components are the before defined age-specific risks or age structures of the whole population or sub-population with confirmed infection. This would help to reveal the reasons for observed differences among the countries as well as to distinguish the real differences in intensity of the studied process (e.g. fatality of the disease) and unavoidable contribution of the age structure.

For the analysis, only a few countries could be selected. The selection was based not only on the data availability (although it is still an important factor) but also on several epidemiological features of the illness in the country selected. The aim was to select such populations, where the illness played an important role and enough observations (confirmed cases, deaths) are available for the quantitative study. Additionally, the analyzed countries have to be comparable, i.e. have some similarities which determine similar potential in the fight with the illness.

[1] All the terms are defined below.

For the study, Italy, Spain, Germany, and South Korea were chosen. The process of the selection of the studied countries is described below after setting the theoretical framework, the introduction of databases, and above all the measures and methods used in the analytical part. Results are discussed and interpreted in the last part of the paper.

2. Health Demography

The study of health issues has become an important part of demographic research, as it is closely related to the process of mortality and its crucial underlying factors (Siegel 2012, Thomas 2017). This is reflected also in the main demographic theoretical concepts related to mortality and morbidity development – the epidemiologic transition and following up hypotheses (cardiovascular revolution). Most of them agree about the decline in the incidence as well as fatality and mortality rates from infectious diseases during the 20th century (Omran 1971; Meslé, Vallin 2002; Olshansky, Ault 1986). On the other hand, some authors (Cliff et al. 2009) alert, that new or re-emerging infectious diseases have to be taken into account.

Demography is traditionally defined as the study of reproduction and its main determinants and consequences in a population. Epidemiology is understood as a study of diseases and its determinants and consequences in a population. It is clear, that these two fields are highly overlapping, particularly according to the study of mortality, morbidity, or population aging (Siegel 2012). Common topics can be seen in the methodological issues as well as in the content focus of the analysis. While Omran (1974) highlights the broader scope of epidemiology and the possibility of using epidemiological methods in demographic research, Siegel (2012) defines the health demography as the application of demographic methods, approaches, and knowledge in the analysis of health and health status. Thomas (2018) defines health demography as a branch of applied demography.

Concerning the brief definition of health demography, knowledge of demographic characteristics of the total population and population affected by the illness is crucial for deeper and more detailed epidemiologic research. Also, it is often an important input for epidemic models (Jing, Jin, Zhang 2018; Inaba 2017).

Siegel (2012) defines health demography as a multidisciplinary approach to the issue, as it is related not only to demography and epidemiology. Above all concerning infectious diseases and large-scale epidemics and pandemics, there is also the crucial aspect of historical studies. For historical plagues, Signoli et al. (2002) concluded that the total number and age structure of victims is closely related to the age structure of the whole population. In today's populations, it is assumed that the effect of the overall population structure is lower as the preventive measures more or less protect the more endangered sub-populations and as the medical care manages to better treat the illness. The similar age structure of the victims and the overall population observed in the past could be interpreted as the consequence of the "non-selective" plague (Signoli et al. 2002).

The current pandemic is expected to be riskier for older age groups (European Centre for Disease Prevention and Control 2020a, Rubino et al. 2020), so the overall age structure may contribute to impacts of the illness but likely in much smaller grade in comparison to historical periods. On the other hand, it could be expected that the overall number of deaths (adjusted for the population size, i.e. the lethality rate) is much more predetermined by the successes of prevention (and level of age-specific incidence resulting from it) and medical care and treatment (i.e. the risk of death of the persons with confirmed infection). Both the assumptions are studied below using the methods of demographic analysis, therefore, the presented research can be fully included in the concept of health demography.

The contemporary world, globalization, and standards of living, may play a crucial role in the outbreak and spread of infectious diseases. There are huge geographical differences in the health status of the overall population as well as the mortality rates caused by infectious diseases. Those regional patterns could be tied with economic and social conditions (Zacher, Keefe 2008; Thomas 2018). Also concerning the COVID-19 pandemic, the geographical differences are observed, however, they are not related solely to the economic and social development of the country. Among others, the potential role of air pollution started to be discussed too (Ogen 2020).

Moreover, within more homogeneous parts of the world many behavioral, cultural, and social variations exist. Those should be considered in any analysis related to health issues, above all the communicable diseases. In one of the most recent researches, Mogi and Spijker (2020) studied such differences in Europe and proved their importance for the spread of the COVID-19 disease.

Based on the concept of health demography, the demographic factors are considered as crucial in influencing the conditions for the spread and severity of communicable diseases as well as their impacts on society (Thomas 2018; Rubino et al. 2020; Distante, Piscitelli, Miani 2020). In this relation, the process of population aging cannot be neglected. The increasing risk of death with age could be considered as the most important factor because of the rapidly aging European population, where the proportion of seniors is very high. In this aspect, Italy as one of the most affected countries has also the highest proportion of seniors in Europe and one of the highest in the world (Rubino et al. 2020; Jodlová, Hulíková Tesárková 2019). However, other European populations are not in a much easier situation. Older people more often suffer from some health limitations or disabilities (Clark, Rees 2017; Olshansky, Ault 1986), which again could be a risk factor in this COVID-19 pandemic.

As only briefly mentioned, many aspects could be studied with the current pandemics and its spread in the world. In this paper, according to the concept of health demography, the main demographic features are considered – age and sex.

3. Data and methods

3.1. Data used in the analysis

There are currently many potential data sources for the COVID-19 pandemic in the world. Considering only databases containing data from more countries (enabling the international comparison), not all of them are suitable for analysis using the demographic approach, while in particular databases e.g. the age or age groups of the confirmed cases are missing or defined differently (e.g. Xu, Gutierrez, Mekaru 2020) or the age variable is not available at all (WHO 2020a, European Centre for Disease Prevention and Control 2020b, Worldometers 2020, Global Change Data Lab 2020a). In the case of an enhanced data file from the European Centre for Disease Prevention and Control (2020b),[2] where the information about age is included, the age groups are rather too wide for an age-specific analysis (10 or 15 years).

One of the latest available databases, which is aimed at the demographic analysis, is the COVerAGE-DB: COVID-19 cases and deaths by age Database (Riffe, Acosta et al. 2020). There is data about confirmed cases and reported deaths from COVID-19 available from several countries, in the time of this analysis the work continues and more countries and data are added. The data was harmonized and classified into 5years or 10years groups of age. Data from this database was used in the analysis below, although it could change in the future as the data is refined. The database was released on April 11, 2020, and the data was downloaded on May 1, 2020.

In the database, in the time of this analysis, there were more than 209,000 of confirmed cases in Spain (most recent data from April 26, 2020), more than 177,000 in Italy (most recent data from April 23, 2020), more than 155,000 in Germany (April 26, 2020) and almost only 11,000 in South Korea (April 28, 2020). For the four analyzed countries, there were almost 53,000 of recorded deaths, most of them in Spain (23.5 thousand) and Italy (23.2 thousand), in Germany, there were only 5,750 recorded deaths from COVID-19 and in Korea only 244 (Riffe, Acosta et al. 2020). All the cases and deaths are cumulated to the latest available date.

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[2] https://qap.ecdc.europa.eu/public/extensions/COVID-19/COVID-19.html (accessed on April 26, 2020)

In this paper, more data sources are combined. We used the Global Change Data Lab (2020a) database for the general description of international differences in the main commonly used measures. Data about the general measures could be taken from other databases too. For the detailed demographic analysis, however, much of the general databases cannot be used because of the absence of age identification. In the analytic part, the COVerAGE-DB: COVID-19 cases and deaths by age Database (Riffe, Acosta et al. 2020) was used, as offering data about the age structure of the confirmed cases as well as victims of the disease. Population data (population by age and sex at the beginning of the last available year) was extracted from the Human Mortality Database (2020).

3.2. Definition of the summary measures

Reports about the overall situation of the pandemic in the world are often based on some generalized summary measures (usually published in multiple databases). Those are often the cumulative number of confirmed cases[3] at the time t (within this paper represented by the symbol C_t) or deaths (D_t) or those numbers divided by the population size (expressed usually per 100,000 inhabitants). Those relative measures are then

$ir_t = 100\,000 \times \frac{C_t}{P_t}$ as the crude rate of cumulative incidence and

$lr_t = 100\,000 \times \frac{D_t}{P_t}$ as the crude lethality rate, also called as "Coronavirus (COVID-19) Mortality Rate" (Worldometers 2020).

In the equations, P_t stands for the population size. In demography, in the crude rates (where the number of events registered during a year is divided by the population size), the population size is considered as the size in the middle of the year. However, in the case presented in this paper, the registered numbers of cases (infection or death) are not observed during the whole year. Using the population size in the middle of the year would not correspond to the population under risk. The closest population size to the observed events is the population size at the beginning of the year 2020. While this population size is not available for any of the studied countries yet, it was estimated as the extrapolation from previous years (under the assumption of the continuation of average annual population changes in particular age groups observed from 2016). The aim of this step was only the estimation of the approximate population size corresponding to the studied process,

[3] In the whole text, the confirmed cases are understood as confirmed cases of COVID-19, numbers of deaths are understood as registered numbers of death related to COVID-19 diagnose.

so we allowed the described simplification. If not stated otherwise, this estimation is used as the population size in all the following calculations.

The rate of fatality (labeled also as "case fatality rate", cfr_t) at time *t* is then expressed (usually in %) as the ratio of a cumulative number of reported deaths until time *t* and cumulative confirmed number of cases at time *t* (Global Change Data Lab 2020a):

$$cfr_t = 100 \times \frac{D_t}{C_t}$$

From a demographic point of view, all these crude rates are influenced by the age structure of the overall population or the sub-population with confirmed infection. Because those measures are not adjusted for differences in the age structures, they are not fully comparable among the countries (Rubino et al. 2020).

In the first part of the analysis, those basic measures are presented for the analyzed countries together with a description of the related age structures. For this aim, the age pyramids are used or calculation of the proportion of seniors (hereinafter defined by the age 65 and more years) and children (hereinafter defined by the age of 19 and fewer years) in the population (total population or population of confirmed cases). Then the age-specific rates are calculated – i.e. ratio of the cumulative number of events (confirmed infection, reported death) at the age group $x–(x+n)$, where n equals to the width of the used age group, and the population size of the same age group.

The age-specific rates of cumulative incidence could be written as:

$$cir_{x-(x+n),t} = 100\,000 \times \frac{C_{x-(x+n),t}}{P_{x-(x+n),t}}$$

The age-specific lethality rates could be defined as:

$$lr_{x-(x+n),t} = 100\,000 \times \frac{D_{x-(x+n),t}}{P_{x-(x+n),t}}$$

and age-specific fatality rates as:

$$fr_{x-(x+n),t} = 100 \times \frac{D_{x-(x+n),t}}{C_{x-(x+n),t}}$$

Concerning the introduced measures as well as data sources, several important facts have to be added and kept in mind in the interpretation and international comparison of the data. First, there is a possibility of an underestimation of the confirmed number of cases as well as deaths related to the studied disease. This might be caused by more reasons such as testing focused on symptomatic persons only, or insufficient testing in general. The level of potential bias will be possible to estimate after the pandemic subsidies (Rubino et al. 2020). Other aspects worth noting are the regional and local differences in the course and features of the infection (Distante, Piscitelli, Miani 2020). However, we dare to take them beyond the scope of the paper due to its focus and main goals.

3.3. Methods

Using the age-specific rates it is possible to compare the analyzed countries. It can be done using the graphical analysis, where the age patterns are visible. Following the aim of the paper, the age-specific rates and age structures are used for analysis. This helps to explain the observed differences in the values of the general measures (crude rates) among the countries.

If the summary measure (the crude rates or case fatality rate) can be expressed as a composition of particular constituent parts, then using some suitable methods (methods of decomposition) differences in their values in the compared populations could be decomposed into specific components (Canudas Romo 2003). In demography, decomposition of the biometric functions (functions of the life table) or the crude rates is applied most often. The latter ones could be considered also for the decomposition of the measures used in this paper.

The difference in the crude rate between two compared populations (*A* and *B*) can be decomposed into the effect of intensity (e.g. age-specific rates) and effect of composition (age-structure) of the population (Kitagawa 1955, Canudas Romo 2003). Considering the measures used in this paper, they can be rewritten so that the structures and intensities are distinguished:

$$cfr_t = 100 \times \frac{D_t}{C_t} = 100 \times \frac{\sum_x D_{x-(x+n),t}}{C_t} = 100 \times \frac{\sum_x C_{x-(x+n),t} \times fr_{x-(x+n),t}}{C_t}$$
$$= 100 \times \sum_x ai_{x-(x+n),t} \times fr_{x-(x+n),t}$$

Where $ai_{x-(x+n),t} = \frac{C_{x-(x+n),t}}{C_t}$ is the relative age structure of confirmed COVID-19 cases.

$$ir_t = 100\,000 \times \frac{C_t}{P_t} = 100\,000 \times \frac{\sum_x C_{x-(x+n),t}}{P_t} = 100\,000 \times \frac{\sum_x P_{x-(x+n),t} \times cir_{x-(x+n),t}}{P_t}$$
$$= 100\,000 \times \sum_x a_{x-(x+n),t} \times cir_{x-(x+n),t}$$

$$lr_t = 100\,000 \times \frac{D_t}{P_t} = 100\,000 * \frac{\sum_x D_{x-(x+n),t}}{P_t} = 100\,000 \times \frac{\sum_x C_{x-(x+n),t} \times fr_{x-(x+n),t}}{P_t}$$
$$= 100\,000 \times \frac{\sum_x P_{x-(x+n),t} \times cir_{x-(x+n),t} \times fr_{x-(x+n),t}}{P_t}$$
$$= 100\,000 \times \sum_x a_{x-(x+n),t} \times cir_{x-(x+n),t} \times fr_{x-(x+n),t}$$

Where $a_{x-(x+n),t} = \frac{P_{x-(x+n),t}}{P_t}$ is the relative age structure of the overall population.

3.3.1. Decomposition of differences in the case fatality rates and crude rates of cumulative incidence

For the case fatality rate (cfr_t) the overall measure could be decomposed into the effect of age-specific fatality rate (effect of intensity) and effect of the age structure of the confirmed cases (effect of structure). For the crude rate of cumulative incidence (ir_t) the effect of structure would represent the age structure of the overall population and the effect of intensity would be tied with the age-specific rates of cumulative incidence.

The decomposition according to Kitagawa (1955) could be written as

$$cfr_t^A - cfr_t^B = \sum_x \frac{ai_{x-(x+n),t}^A + ai_{x-(x+n),t}^B}{2} \times \left(fr_{x-(x+n),t}^A - fr_{x-(x+n),t}^B\right) + \sum_x \frac{fr_{x-(x+n),t}^A + fr_{x-(x+n),t}^B}{2} \times \left(ai_{x-(x+n),t}^A - ai_{x-(x+n),t}^B\right)$$

$$ir_t^A - ir_t^B = \sum_x \frac{a_{x-(x+n),t}^A + a_{x-(x+n),t}^B}{2} \times \left(cir_{x-(x+n),t}^A - cir_{x-(x+n),t}^B\right) + \sum_x \frac{cir_{x-(x+n),t}^A + cir_{x-(x+n),t}^B}{2} \times \left(a_{x-(x+n),t}^A - a_{x-(x+n),t}^B\right)$$

In both cases the first term is the effect of intensity, the second term is the effect of structure. These two effects could work simultaneously (in the same direction) or contradictory. The effect of intensity reveals the real differences in the level of fatalities or cumulative incidence. Those differences could be supported or reduced by the effect of a particular age structure.

3.3.2. Decomposition of differences in the crude lethality rates

Concerning the potential expression of particular effects, the most interesting case is the crude lethality rate (COVID-19 Mortality Rate). This measure could be decomposed into the effect of the age structure of the population, and two effects of intensity – effect of incidence and fatality. However, this cannot be done by the above-presented method of decomposition. In this case, the decomposition method which is less known also for many demographers has to be applied. This is so-called polar decomposition (Zeng et al. 1991; Dietzenbacher, Los 1998; Caundas Romo 2003). The polar decomposition of the crude lethality rate could be written as (according to Caundas Romo 2003):

$$lr_t^A - lr_t^B = \frac{1}{2} \times \left[\begin{array}{l} \sum_x \left(a^A_{x-(x+n),t} - a^B_{x-(x+n),t} \right) \times cir^B_{x-(x+n),t} \times fr^B_{x-(x+n),t} + \\ + \sum_x \left(a^A_{x-(x+n),t} - a^B_{x-(x+n),t} \right) \times cir^A_{x-(x+n),t} \times fr^A_{x-(x+n),t} \end{array} \right] +$$

$$+ \frac{1}{2} \times \left[\begin{array}{l} \sum_x a^A_{x-(x+n),t} \times \left(cir^A_{x-(x+n),t} - cir^B_{x-(x+n),t} \right) \times fr^B_{x-(x+n),t} + \\ + \sum_x a^B_{x-(x+n),t} \times \left(cir^A_{x-(x+n),t} - cir^B_{x-(x+n),t} \right) \times fr^A_{x-(x+n),t} \end{array} \right] +$$

$$+ \frac{1}{2} \times \left[\begin{array}{l} \sum_x a^A_{x-(x+n),t} \times cir^A_{x-(x+n),t} \times \left(fr^A_{x-(x+n),t} - fr^B_{x-(x+n),t} \right) + \\ + \sum_x a^B_{x-(x+n),t} \times cir^B_{x-(x+n),t} \times \left(fr^A_{x-(x+n),t} - fr^B_{x-(x+n),t} \right) \end{array} \right]$$

Using this type of decomposition, it is possible to compare the studied countries according to the overall lethality level – the observed differences between the countries could be easily explained by the pure effect of differences in the level of age-specific incidence, age-specific fatality and their reduction or increase caused by different age structures. Using this method, it is possible to quantitatively express the importance of the age structure of the population for the differences in lethality rate, discuss the effectivity of prevention leading to the reduction of the lethality rate through the age-specific incidences or effectivity of treatment leading to reduction of lethality through the age-specific fatality rates themselves.

3.3.3. Potential reduction of the number of registered cases and deaths

As the results are more illustrative, for the concluding discussion of the results a simple model scenario of the potential decrease of the number of registered cases and deaths is prepared. This model reduction is calculated as the difference between the observed numbers for each country and potentially reachable ones. In the calculation of potential numbers of registered cases $(C_t^{potential})$ or deaths $(D_t^{potential})$, the real age structures of the studied countries (i) are used, however, the age-specific incidence rates, as well as fatality rates, are equated to the lowest ones observed among the countries $(cir^{i=best}_{x-(x+n),t}$ and $fr^{i=best}_{x-(x+n),t})$:

$$C_t^{potential} = \sum_x P^i_{x-(x+n),t} \times cir^{i=best}_{x-(x+n),t}$$

$$D_t^{potential} = \sum_x P^i_{x-(x+n),t} \times cir^{i=best}_{x-(x+n),t} \times fr^{i=best}_{x-(x+n),t}$$

4. Country comparison

For the basic international comparison of the state of the pandemics as well as for the selection of countries suitable for this study, we used the basic statistics from the Global Change Data Lab (2020b). For all the countries in the database, it was possible to compare the relation between the total number of confirmed cases and the total number of deaths related to COVID-19. The latest data used in this paper is from April 30, 2020. In Figure 1 the results are presented. On both axes, the logarithmic scales were used, which enables us to show more details for countries with small numbers of cases or deaths. From Figure 1 it is visible, that there is (logically) a relation between the total number of confirmed cases of COVID-19 and the total number of deaths due to this illness in the World. In many countries, the number of cases as well as the number of deaths is relatively low. A group of countries with higher numbers of observations could be identified in the graph – the USA, Spain, Italy, Great Britain, France, Iran, China, Belgium, and Germany belong to this group. For comparison, the situation in South Korea

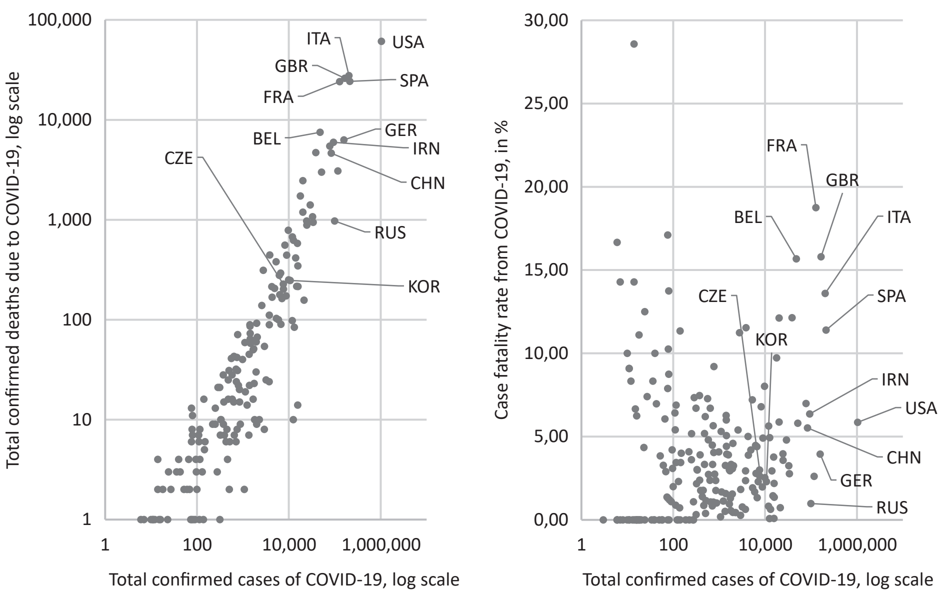

Fig. 1 – Total number of confirmed cases of COVID-19 and the total number of confirmed deaths due to COVID-19 (left, logarithmic scale on both axes); Total number of confirmed cases of COVID-19 and case fatality rate from COVID-19 (right, logarithmic scale on the horizontal axis), April 30, 2020. Note: BEL – Belgium, CZE – Czechia, FRA – France, GBR – Great Britain, GER – Germany, CHN – China, KOR – South Korea, IRN – Iran, ITA – Italy, RUS – Russia, SPA – Spain, USA – the United States of America. Source of data: Global Change Data Lab 2020b.

is highlighted too in the Figure, because the total number of inhabitants in South Korea (more than 50 million) is between Spain (almost 47 million) and Italy (around 60 million; Human Mortality Database 2020). Despite the total number of inhabitants in South Korea, the number of confirmed cases is several times lower than in Italy or Spain.

With the knowledge of the total number of cases as well as the total number of deaths, it is easy to calculate the overall rate of fatality (case fatality rate) as a ratio of the number of deaths and the number of confirmed cases. In Figure 1, visibly there is a U-shape of the crude fatality rate to the log of total confirmed cases. In other words, there is a higher case fatality rate in countries with a very low number of confirmed cases as well as with the highest numbers of confirmed cases. On both tails of the curve, the variability is relatively high. The first group of countries, where the numbers of confirmed cases of infection are low, however, the case fatality rate is high, those are above all the developing countries where insufficient testing of the population could be supposed. That means that confirmed cases are likely the serious ones with many symptoms and so with a higher probability of death. In this group of countries, the highest case fatality rate is observed in Nicaragua (case fatality rate equals to 28.57% with only 14 confirmed cases). To the same group of countries (with relatively low numbers of registered cases and high case fatality rate) belong also Algeria, Bahamas, Belize, Guyana, Liberia, Mauritania, or Zimbabwe (Global Change Data Lab 2020b).

On the other hand, among countries with the highest numbers of confirmed cases, there are currently (April 30, 2020) the USA, Spain, Italy, France, Great Britain, China, Russia, or Germany. However, there are significant differences in the case fatality rate within this group of countries. While the case fatality rate in Germany is below 4%, in France it reaches almost 19%, in Italy, it is 13.6%, in Great Britain 15.8% or Spain 11.4% (Fig. 1). The case fatality rate in South Korea is low (2.3%) and comparable to Germany, although the total number of confirmed cases is very different.

For comparison, the case fatality rate was calculated also incorporating time delay in the number of registered cases. In Figure 2, there is the case fatality rate calculated as the ratio of the number of deaths from April 30, and the number of registered cases by April 16, 2020. This approach is based on the assumption of a time delay between the case registration and death. Using this approach, for many countries the case fatality rate is higher – e.g. for Sweden, Great Britain, Belgium, or France the case fatality rate reached more than 20%, similar to Algeria and approaching Mexico. In Figure 2, there are some countries not depicted at all because of the very extreme case fatality rates calculated in this way – e.g. Sudan (87.5%, only 32 registered cases by April 16), Nicaragua (44.4%), or Somalia (35%). However, although this approach may be closer to reality, where some time delay between confirmation of the illness and death could be expected, this approach

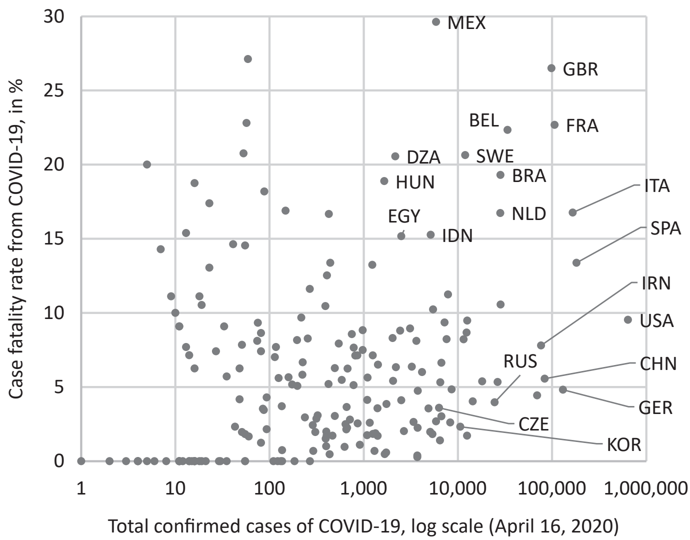

Fig. 2 – Total number of confirmed cases of COVID-19 (April 16, 2020) and case fatality rate from COVID-19 (where deaths were cumulated to April 30 and numbers of registered cases to April 16, 2020), logarithmic scale on the horizontal axis. Note: BEL – Belgium, BRA – Brazil, CZE – Czechia, DZA – Algeria, EGY – Egypt, FRA – France, GBR – Great Britain, GER – Germany, HUN – Hungary, CHN – China, KOR – South Korea, IND – India, IRN – Iran, ITA – Italy, MEX – Mexico, NLD – Netherlands, RUS – Russia, SPA – Spain, SWE – Sweden, USA – the United States of America. Source of data: Global Change Data Lab 2020b.

is usually not used in practice and the case fatality rate is calculated as presented above. This more common form is used in the rest of the paper.

Based on the presented results of the simple descriptive characteristics, Italy and Spain were selected for the analysis as two countries with almost the highest numbers of confirmed cases (except for the USA) which also belong to the group of countries with the highest case fatality rate. Germany was selected as a country with a high number of confirmed cases where, however, the case fatality rate was relatively low. And South Korea was selected as a representative of the countries with an almost similar number of inhabitants but a much lower number of confirmed cases, where the case fatality rate was very low (from the analyzed countries it is comparable only to Germany). It would be interesting to analyze also countries like France with probably the highest case fatality rate among the countries with the highest number of confirmed cases, or the USA with the highest number of confirmed cases so far (April 30, 2020). Unfortunately, before the analysis of this paper was processed (mid-April, 2020), data for France as well as for the USA were not available in the database used in this study (Riffe, Acosta et al. 2020). This might be a promising issue for any future study.

Table 1 – Basic demographic and epidemiologic characteristics of the studied countries

	Italy	Germany	South Korea	Spain
Population size (mil.; estimation for the January 1, 2020)	60.1	84.3	51.6	46.8
Age structure (in %)				
Age 0–19	17.9	18.5	17.8	19.8
Age 20–64	58.9	59.7	67.0	60.5
Age 65+	23.2	21.8	15.2	19.7
Total number of confirmed cases of the infection				
Females	91,115	81,207	6,408	116,834
Males	86,029	73,986	4,344	92,631
Both sexes	117,143	155,193	10,752	209,465
Proportion of males (in %)	48.6	47.7	40.4	44.2
Age structure of the population with confirmed infection (in %, both sexes)				
Age 0–19	1.9	5.1	6.8	0.9
Age 20–64	51.3	71.3	76.9	54.5
Age 65+	46.8	23.6	16.4	44.6
Total number of registered deaths				
Both sexes	23,188	5,750	244	23,521
Summary measures				
Crude rate of cumulative incidence (cases per 100,000 of inhabitants)	294.5	184.2	20.8	447.1
Crude lethality rate (deaths per 100,000 of inhabitants)	38.6	6.8	0.5	50.2
Case fatality rate (deaths per 100 confirmed cases)	13.1	3.7	2.3	11.2

Note: The incidence, fatality, and mortality in the Table are considered as related to the COVID-19 only. Numbers of cases, as well as the case fatality rates in this table, could differ slightly from the values in Figure 1, the reason is not only different sources of data but also the different dates of registration of the cases.
Source of data: Human Mortality Database 2020 (data for the beginning of the year 2020 were simply estimated by extrapolation from the latest years where data were available); Riffe, Acosta et al. 2020 (numbers of confirmed cases, as well as deaths, are cumulated numbers, the most recent data is used in the analysis, i.e. data from April 23, 2020, for Italy, April 26, 2020, for Germany and Spain, and April 28, 2020, for South Korea); author's calculation

In Table 1 some selected basic characteristics of the studied countries are summarized. All the selected countries are similar according to the proportion of children in the population (between 17.8 and 19.8%), however, the proportion of the population aged 65 and more is different – Italy is the oldest country among them with 23.2% of seniors aged 65 and more. The proportion is similar in Germany (21.8%) and Spain (19.7%), however, in South Korea it is visibly lower (15.2%) and its population in productive age is more represented (Table 1).

It has to be added, that not all the studied countries are in the same phase of the disease, it has to be kept in mind while using the data and interpreting the results. From the four selected countries, South Korea was the first one, where the infection was confirmed – it was on January 20, 2020, and South Korea was one of the first countries in the world with a confirmed infection (Dzúrová, Jarolímek

2020). On January 27 the first case of infection was confirmed in Germany, on January 31 it was Spain and Italy (Ravelo, Jerving 2020; WHO 2020b; Dzúrová, Jarolímek 2020). Because the data from the database used in the study (Riffe, Acosta et al. 2020) are cumulated to April 23, 2020, for Italy, April 26, 2020, for Germany and Spain, and April 28, 2020, for South Korea, the used total numbers of deaths and confirmed cases represent 99th day of the infection in South Korea, 90th day of infection in Germany, 86th day in Spain and 83rd day in Italy. For these three European countries, it could be supposed, that the epidemics could be in a similar phase, the situation in South Korea is more developed.[4]

On the other hand, the development of the pandemics in all the studied countries was different, as well as the reaction of the society in general. In South Korea, the preventive measures were influenced by the previous epidemics, which Korea went through in the past. The prevention was focused above all on the quick reaction of the government, an immediate start of the free nationwide testing, and access to information (Lee 2020, United Nations Development Programme 2020). Prevention in Germany was focused above all on the protection of seniors (The Federal Ministry of Health, Germany 2020). In Korea as well as in Germany, there is high attention paid to the spread of the infection among medical staff. The population of positively tested medical staff is usually younger and with a higher proportion of females, e.g. in Germany 72% of confirmed infected medical staff were females and the median age was only 42 years (Robert Koch Institut, Germany 2020). In Italy and Spain, there are persistent regional differences in the testing and capacities of tests and preventive measures which were gradually tightened (WHO 2020b, WHO 2020c).

So far, the daily numbers of new cases culminated in Spain on April 1, in Italy, it was on March 21, in Germany on March 20, and in South Korea already on February 29. The numbers of daily new confirmed cases in South Korea seem to be rather stable and very low at least from mid-April 2020. It means, that the peak of the epidemics seems to be over in all the analyzed countries, despite some temporary variations.

Another difference among the studied countries could be observed in the sex structure of the population with confirmed infection – in all the studied countries, there are more females among the positively tested people, in Italy, the proportion of males is the highest one (48.6%). In South Korea, the proportion of males among the positively tested is significantly lower (40.4%, Table 1).

Differences in the case fatality rate among the selected countries are confirmed. In Table 1 the case fatality rates are expressed for 100 confirmed cases (in %). Its value is nearly the same in Italy and Spain (13.1%, 11.2% resp.), however, it is

[4] https://who.sprinklr.com/, accessed on 2020-04-13

visibly lower for Germany (3.7%) and above all for South Korea (2.3%). The phase of the epidemics is not the most important reason for the observed differences in fatality rates.

From the other results in Table 1, it may seem, that the reason for the very low case fatality rates in South Korea lies in the overall younger age structure of the Korean population as well as the younger age structure of the positively tested Korean population. In South Korea, there are only 16.4% of people aged 65 and more years among the registered cases of infection (for comparison, in Italy and Spain this proportion was 46.8% and 44.6% resp.). In Germany, the percentage of seniors among confirmed infected inhabitants is also relatively low, only 23.6%. This could be taken as an explanation for the lower case fatality rate in Germany in comparison to Italy and Spain. On the other hand, the proportion of seniors aged 65 and over among positively tested people is quite similar in Germany and South Korea, but the case fatality rates differ (although not too much) and the crude lethality rate (deaths per 100,000 of inhabitants) from COVID-19 are 14-times higher in Germany than in South Korea (although the crude lethality rates in Italy and Spain are almost incomparable to Germany and Korea, see Table 1).

To summarize, the observed differences in the case fatality rates and the defined crude rates are likely to be explained at least partly by the age structure of the population in general, partly by the age structure of the positively tested population and partly by the intensities of the process (age-specific rates) themselves. The intensities, as well as the age structures of the studied populations, are presented below and in Figures 3–6. Using the decomposition techniques, their particular effects are estimated in the following step.

5. Comparison of selected countries

As was stated above, the case fatality rate and also the overall number of deaths or crude rates are affected by the age structure of the total and the positively tested populations and age-specific rates related to the infection. In the four compared countries the age structure of the total population is almost similar except for the lower proportion of people aged 65 and older in South Korea (Table 1, Fig. 3). However, the age structure of the population testing positive for COVID-19 is completely different (Fig. 4).

Unfortunately, in all three European countries, the most affected age-group is the oldest one. This is clear above all for Italy and Spain. In Germany and especially in Korea, the younger age groups are also highly represented – between 20 and 35 years. Clearly in Korea, among those young confirmed cases, there is a higher proportion of females (in Germany the difference between sexes is not so visible). This might correspond with the infection of the medical staff. Clearly, in Korea,

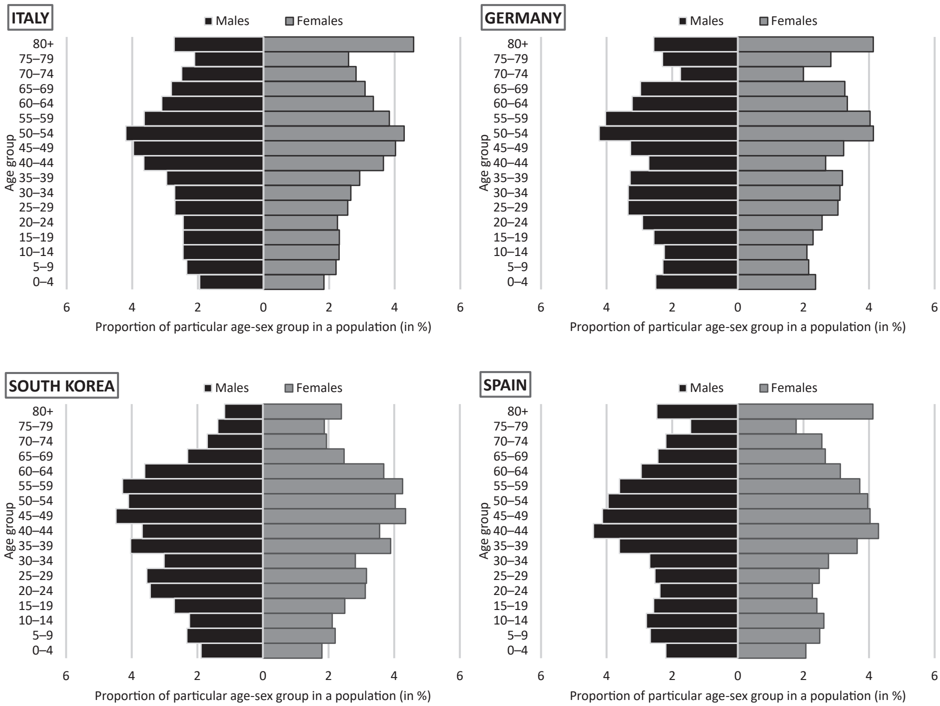

Fig. 3 – Relative age structure (in %) of the studied populations (estimation for January 1, 2020). Source: Human Mortality Database 2020, author's calculation.

the proportion of seniors among the confirmed cases is very low, as was presented already in Table 1.

Concerning the European countries, a question could arise, how much the observed age structure of confirmed cases corresponds to the overall age structure of the whole population. Without a direct comparison, one can assume, that the old age structure of the sub-population with confirmed infection is the consequence of the overall (old) age structure of the whole population. However, the age structure of the population is not the only factor determining the age structure of the confirmed cases. This could be proved by the example of Germany and Italy. Although the age structures of the population of Italy and Germany are very similar, the age structures of persons with confirmed infection are significantly different (Table 1, Fig. 3, 4). The reason could be traced to the age-specific rates of cumulative incidence. Because of the different phases of the pandemics in the analyzed countries, it could be supposed, that above all in the European countries the number of confirmed cases and incidence rates are likely to increase in the future. Despite the more developed phase of the pandemics in Korea, the age-specific incidence rates are higher in all the European analyzed countries in comparison to South Korea (Fig. 5).

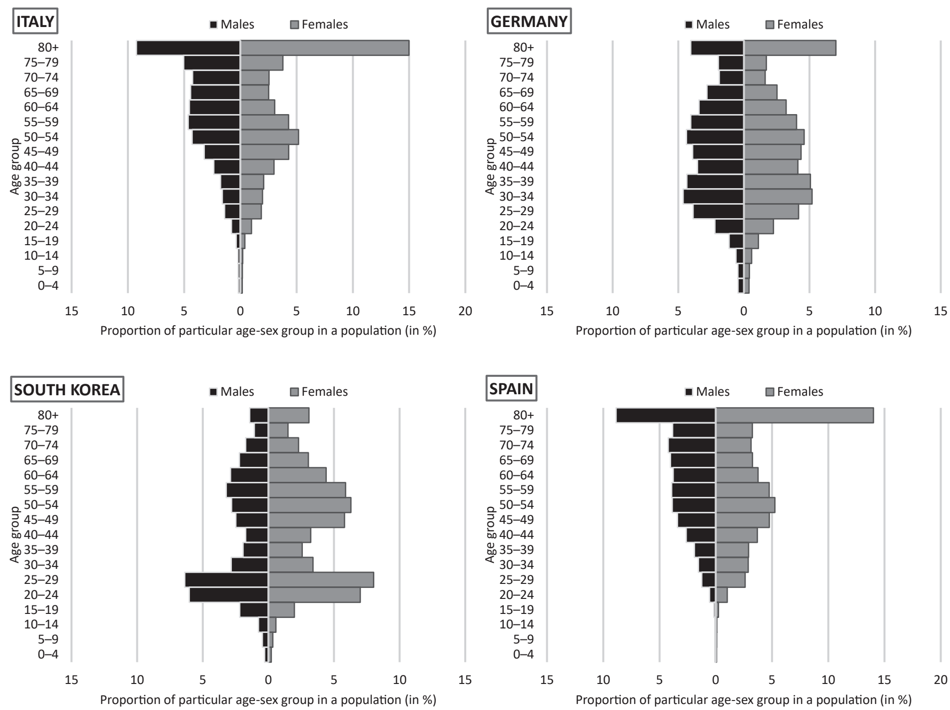

Fig. 4 – Relative age structure of the population testing positive for COVID-19, analyzed countries (in %). Source of data: Riffe, Acosta et al. 2020 (numbers of confirmed cases are cumulated numbers, the most recent data is used in the analysis, i.e. data from April 23, 2020, for Italy, April 26, 2020, for Germany and Spain, and April 28, 2020, for South Korea); author's calculation.

From Figure 5 it could be seen, that the age-specific rates of cumulative incidence are likely to be more important for the above-observed age structures of the confirmed COVID-19 cases than the overall age structure of the studied populations. While in Italy and Spain the age-specific rates of cumulative incidence increase with age (except for a temporary increase of the age-specific rates for females from the ages of 25–34 years and 45–60 what could be related to medical and services workers), in Germany and in particular in South Korea the age-specific incidence rates are increasing at younger ages and then decreasing. In the case of Germany, the incidence rate around the age of 30 is comparable to Italy and Spain. Again, this age group could be related to medical workers or other workers in important services. What is an extremely unfavorable feature observable in Figure 5, it is the rapid increase in the incidence at the highest age groups. The highest value is observed for Spanish men aged 80 and more years. In this age category, on average more than 1,600 of every 100,000 inhabitants were confirmed as infected by the COVID-19 illness by April 26, 2020.

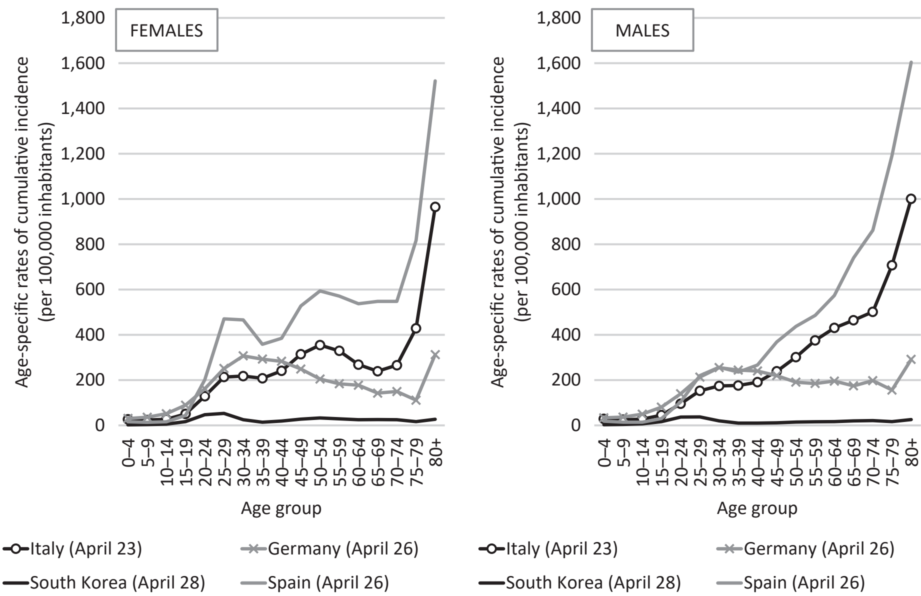

Fig. 5 – Age-specific rates of cumulative incidence (per 100,000 inhabitants) in the analyzed countries. Source: Human Mortality Database 2020 (data for the beginning of the year 2020 was simply estimated by extrapolation from the latest years where data was available); Riffe, Acosta et al. 2020 (numbers of confirmed cases are cumulated numbers, the most recent data is used in the analysis, i.e. data from April 23, 2020, for Italy, April 26, 2020, for Germany and Spain, and April 28, 2020, for South Korea); author's calculation.

The different age structure of persons with the confirmed infection itself could be expected to lead to the different numbers of deaths and case fatality rates in various countries. However, it is not the only factor again. Another aspect that can influence the overall fatality is the age-specific fatality rate, i.e. the proportion of deaths to confirmed cases in each age and sex group. The measure was expressed per 100 confirmed cases (in %, Fig. 6). Again, we have to suppose that the fatality rate could develop in the future.

The values of the fatality rate at the lowest ages lacked significant evidence for complete interpretation because there are only several cases of death observed. The rate of fatality at these ages is highly influenced by random fluctuations. However, from the ages of around 30 years, the age-specific rates of fatality could be followed. In Fig. 6, an exponentially increasing trend with age is visible. This even emphasizes the unfavorable incidence situation in Italy and Spain with a high proportion of seniors among the confirmed cases because their risk of death is the highest.

From the oldest group of males with confirmed infection (aged 80 and more), there are on average more than 40% of cases leading to death in Spain and Italy.

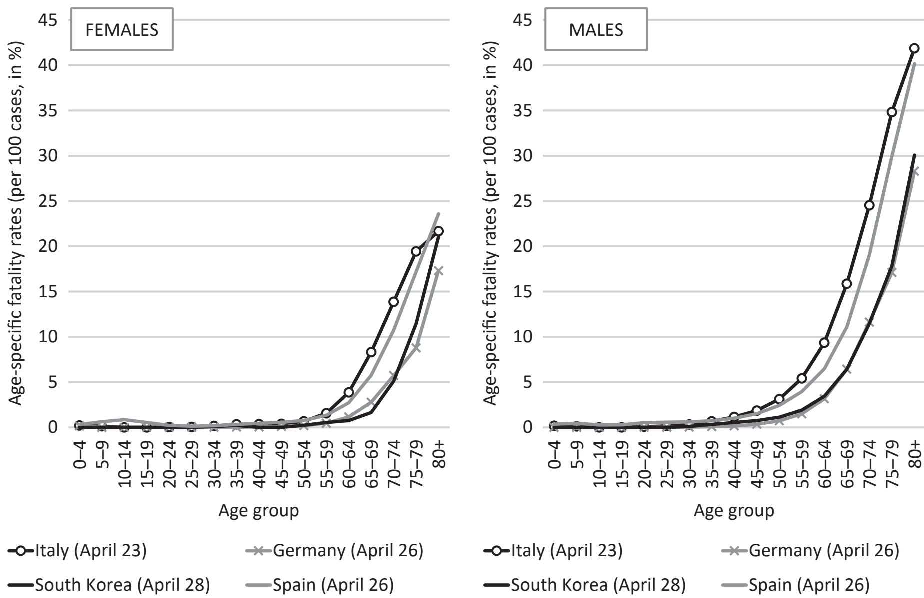

Fig. 6 – Age-specific fatality rates (per 100 confirmed cases) in the analyzed countries. Source: Riffe, Acosta et al. 2020 (numbers of confirmed cases, as well as deaths, are cumulated numbers, the most recent data is used in the analysis, i.e. data from April 23, 2020, for Italy, April 26, 2020, for Germany and Spain, and April 28, 2020, for South Korea); author's calculation.

Among Korean men in the same age group, the rate is 30% and in Germany, it is above 28%. For females, the rates are lower (23.6% in Spain, 21.7% in Italy, 21.1% in South Korea, and only 17.3% in Germany), Figure 6.

Although the overall trend of the age-specific fatality rates is similar in all the analyzed countries, the overall fatality level is higher in Italy and Spain. The values of the fatality rates are nearly the same and at all age groups, they surpass the values of the two other studied countries. In Germany, at some ages (above all senior ages) the age-specific fatality rates are even lower than in South Korea (Fig. 6), however, this may change in the future as the pandemic develops.

To summarize, the age-specific fatality rates are increasing with age in all the studied countries, but their values differ significantly. It is a very unfortunate situation in Italy and Spain, where the proportion of seniors among the confirmed infected inhabitants is the highest one, also the fatality rates of seniors are the highest ones among the studied countries. This combination of factors related to the relatively old age structure of the population, age-specific rates of cumulative incidence (the highest ones in Italy and Spain) and age-specific fatality rates (the highest ones again in Italy and Spain) explains the observed differences in the case fatality rates as well as the crude rates or total numbers of deaths and so the overall severity of the situation.

6. Decomposition of the differences among the countries

As was stated above, it could be supposed, that the observed differences in the crude rates, as well as the case fatality rates (commonly used basic comparative measures), could be at least partly explained by the age structure of the whole population or age structure of the sub-population with confirmed infection of COVID-19 (effect of structure) and the intensity of the process itself represented here by the age-specific rates of cumulative incidence or fatality (effect of incidence).

As was presented, the crude rate of cumulative incidence differs significantly in all the analyzed countries – while in South Korea only 20.8 from all 100,000 inhabitants have been positively tested for COVID-19 so far, in Germany it is 184.2, in Italy 294.5 and Spain even 447.1 (Table 1). In this relation, the question was stated, what proportion of the observed differences is caused by the age structure of the overall population and what was likely the consequence of the age-specific rates of cumulative incidence. While the age structure of the population could be taken as a given characteristic that cannot be changed immediately, the age-specific rates of cumulative incidence reflect e.g. effectivity of prevention, protection of the population, and with a simplifying model approach, it could be taken as an avoidable risk factor. Results of the decomposition of differences in the crude cumulative incidence rates are presented in Figure 7.

The highest differences in the crude rates of cumulative incidence are observed between Spain and South Korea (SPA-KOR) and Italy and South Korea (ITA-KOR). As was stated, behind the overall level of cumulative incidence, there stands the age-specific incidence rate as well as the age structure of the compared populations. From Figure 7 it is visible, that the effect of age structure is relatively small. It is true, that the studied European populations are a bit disadvantaged by their older age structure in comparison to Korea (the effect of age structure contributes to the observed differences in the crude rate), however, the effect of the age structure is only around 3% of the total difference between Spanish and Korean females and slightly above 6% of the difference between Italian and Korean females. For females, the effect of the age structure is the highest for the difference between Spain and Italy, where it decreases the overall difference in the crude rate of cumulative incidence by 11% (i.e. it is the advantage of Spain in comparison to Italy). For males the results are similar, but the values of the effect of the age structure are slightly higher – it contributes by 4.6% to the difference between Spain and Korea and by 7.3% to the difference between Italy and Korea. Also for men, the contribution of the age structure is the most important one (and again in negative values, i.e. contribution to the decrease of the difference of the crude rates) for the difference between Spain and Italy – the potential difference in the crude rate of cumulative incidence between these two countries is decreased by

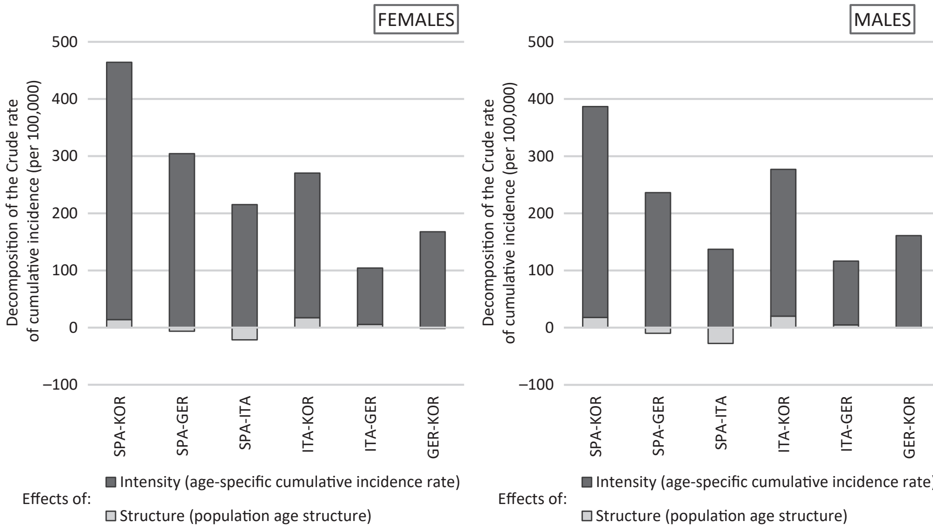

Fig. 7 – Decomposition of the crude rate of cumulative incidence, differences among the analyzed countries. Note: SPA – Spain, GER – Germany, KOR – South Korea, ITA – Italy. Source: Human Mortality Database 2020; Riffe, Acosta et al. 2020 (numbers of confirmed cases, as well as deaths, are cumulated numbers, the most recent data is used in the analysis, i.e. data from April 23, 2020, for Italy, April 26, 2020, for Germany and Spain, and April 28, 2020, for South Korea); author's calculation.

some 25% as the effect of a younger (more advantageous) age structure in Spain in comparison to Italy (Fig. 7).

The case fatality rate is the proportion of all the registered cases leading to death. In Table 1 the values of the case fatality rate reached 13.1% in Italy and 11.2% in Spain in comparison to 3.7% in Germany and 2.3% in South Korea. Again there arose a question, what part of the observed differences among these countries is likely to be caused by the intensity of the fatality process itself (the age-specific fatality rates, which reflects the success of the treatment and the severity of the disease) and by the age structure of the confirmed cases of the disease.

In this case, the effect of age structure and effect of intensity are more balanced (Fig. 8). Above all, for females, the effect of the age structure of the confirmed cases plays an important role in the overall case fatality rate. This is caused by relatively smaller differences in the age-specific fatality rates among the countries (Fig. 6).

The last summary measure used in this paper as well as in many international databases (e.g. Global Change Data Lab 2020a) is the crude lethality rate expressing the overall mortality from the studied infection. In Table 1, a large difference was observed among the studied countries according to the values of this measure. The overall (for both sexes) crude lethality rate in Spain is circa 100-fold higher in comparison to Korea (50.2 vs. 0.5 deaths per 100,000 inhabitants). Crude lethality

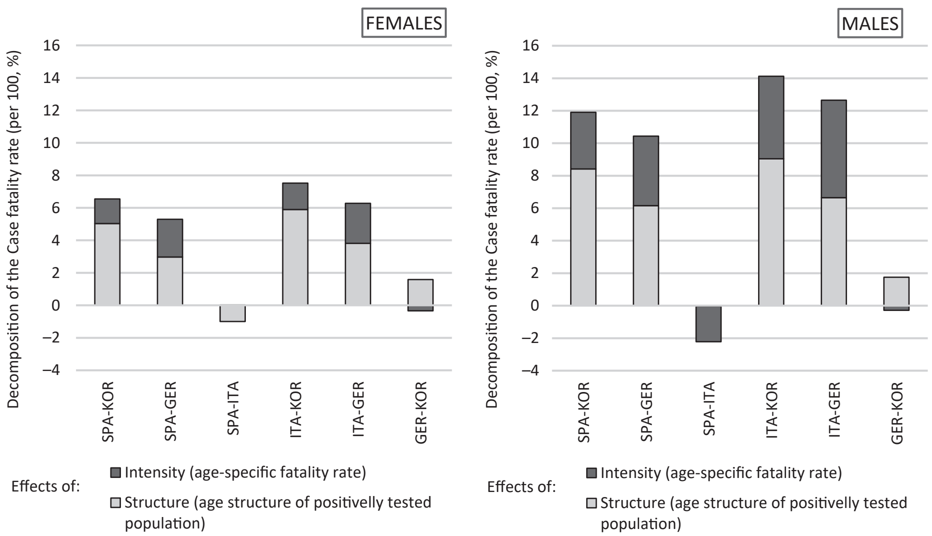

Fig. 8 – Decomposition of the case fatality rate, differences among the analyzed countries. Note: SPA – Spain, GER – Germany, KOR – South Korea, ITA – Italy. Source: Riffe, Acosta et al. 2020 (numbers of confirmed cases, as well as deaths, are cumulated numbers, the most recent data is used in the analysis, i.e. data from April 23, 2020, for Italy, April 26, 2020, for Germany and Spain, and April 28, 2020, for South Korea); author's calculation.

rate in Germany (6.8) is closer to Korea, Italian value (38.6) lies above the average of those countries. Again a question could arise, what are the factors standing behind the observed differences? It was already presented, that in Korea the overall age structure is a bit more favorable in comparison to the three studied European countries. However, the crude rate of cumulative incidence was not affected significantly by the population age structure (Fig. 7). In the case of the crude lethality rate, the effect of the age structure could be stronger because it stands behind and bears two intensities – the intensity of incidence (age-specific rate of cumulative incidence) and age-specific fatality rate. The results of the decomposition of the crude lethality rate are presented in Figure 9.

As could have been expected, the biggest differences are observed between Spain and Korea (SPA–KOR) or Spain and Germany (SPA–GER). This holds for males as for females. In comparison to Germany, there is a small advantage of Spain in its age structure – the negative value of the contribution to the overall observed difference in the crude lethality rates reflects the younger age structure in Spain with a lower proportion of those age-groups (the oldest ones) which are affected by the highest age-specific rates of incidence as well as fatality. In comparison to Korea or Germany, Spain is disadvantaged by higher rates of fatality but above all by higher values of incidence rates. The effect of incidence stands

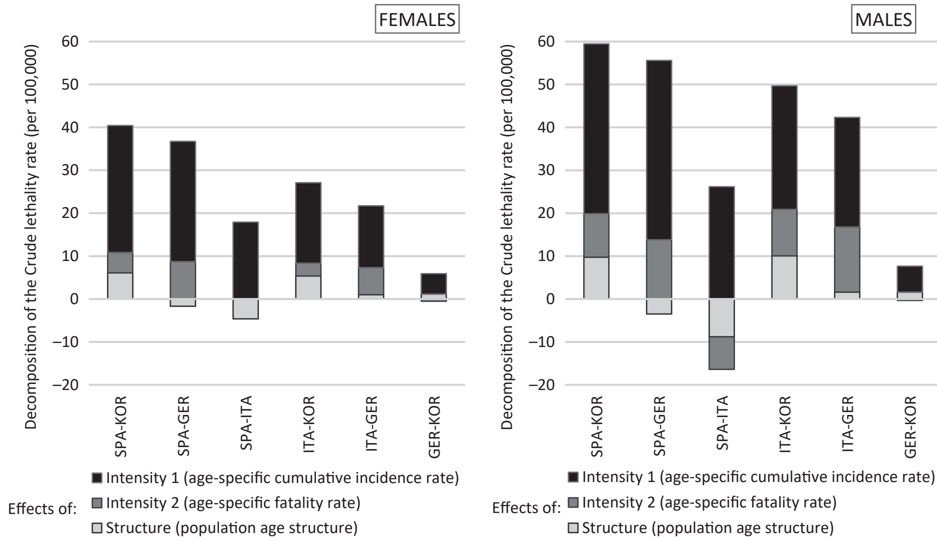

Fig. 9 – Decomposition of the crude lethality rate, differences among the analyzed countries. Note: SPA – Spain, GER – Germany, KOR – South Korea, ITA – Italy. Source: Riffe, Acosta et al. 2020 (numbers of confirmed cases, as well as deaths, are cumulated numbers, the most recent data is used in the analysis, i.e. data from April 23, 2020, for Italy, April 26, 2020, for Germany and Spain, and April 28, 2020, for South Korea); author's calculation.

behind the complete difference between Italy and Spain. Without the advantage of Spain in its younger age structure as well as lower age-specific fatality rates (above all for men), the difference in the crude fatality rates in Spain and Italy would have been even higher.

On the other hand, Italy reached a higher crude lethality rate in comparison to Germany and Korea because of all the three considered effects. The most important of them is the effect of intensity of incidence (causes around 60–70% of the observed difference in the crude lethality rates), the effects of age structure and fatality rates are more balanced, the age structure plays a more significant role in comparison of Italy and Korea – the older age structure of Italy causes around 20% of the observed differences in the crude lethality rates (for both sexes).

Both Germany and Korea reach very low levels of the crude lethality rate. Nevertheless, values in Korea are visibly lower. This is above all the effect of incidence rates – as was presented above, the significant advantage of Korea is its low proportion of seniors in the population with confirmed infection. On the other hand, there is the advantage of Germany in its more favorable fatality rates – it decreases the potential difference in the crude lethality rates between Germany and Korea by some 9.5% for females and 4.5% for males. In this case, the observed difference in the crude lethality rate is again caused partly by the different age structures of the populations. For both sexes, almost 22% of the difference was caused by the less favorable (older) age structure in Germany in comparison to Korea.

7. Potential reduction in the number of registered cases and deaths

From the above-presented results, it is clear that the studied countries differ significantly in how the development of the pandemic progressed, although the reasons might not be the same – e.g. Italy or Spain suffer from very high incidence as well as fatality rates, the advantage of South Korea is a very low incidence rate at higher ages, Germany benefits particularly from very low fatality rates.[5] Although the effect of the age structure for the crude rate of cumulative incidence was not crucial, its impact on the crude fatality rate was not negligible at all.

If the age structure of the population is taken as some unvarying feature which can play a supporting role as well as a hindrance in the international comparison, the age-specific rates of incidence and fatality are the factors potentially influenced by the targeting and effectivity of prevention or the success of the health system and treatment.

As mentioned, for a better illustration of potential improvements in the presented summary measures a model scenario of a possible decrease in the observed registered numbers of cases and deaths is constructed. At first, the potential numbers of cases and deaths for all the countries are estimates. For this aim, the real age structure of each country was used in combination with the most favorable observed age-specific rates of cumulative incidence or fatality ($cir_{x-(x+n),t}^{i=best}$ and $fr_{x-(x+n),t}^{i=best}$).

The most favorable age-specific cumulative incidence rates were observed for Korea (Fig. 5). In the case of age-specific fatality rates, the values for Korea and Germany are very similar. However, from the above-presented decomposition (Fig. 9) it is clear, that the difference in the crude lethality rate between Germany and Korea was reduced by a slightly more favorable fatality in Germany. For some ages, it is visible also in Figure 6.

In the model scenario, the potential numbers of registered cases are calculated using the Korean values of the age-specific cumulative incidence ($cir_{x-(x+n),t}^{i=KOR}$), the potential numbers of registered deaths are calculated using the Korean incidences and German age-specific fatality rates ($fr_{x-(x+n),t}^{i=GER}$).

The potential reduction in the observed numbers is then simply the difference between the observed numbers of registered cases and deaths and the calculated potential ones. The results are summarized in Table 2.

[5] Because the studied countries are not at the end of the epidemic, the observed numbers of confirmed cases as well as deaths are likely to increase.

Table 2 – Potential reduction of the numbers of confirmed cases or deaths in the analyzed countries, both sexes, estimations are done to the date of the most recent data, condition of reaching the most favorable age-specific cumulative incidence and fatality rates

Both sexes	Italy (April 23)	Germany (April 26)	South Korea (April 28)	Spain (April 26)
Potential numbers of confirmed cases of infection	12,332	17,506	10,752	9,314
Observed numbers of cases	177,143	155,193	10,752	209,465
Potential reduction in the number of cases	*164,811*	*137,687*	*0*	*200,151*
Potential numbers of deaths	431	562	225	293
Observed numbers of deaths	23,188	5,750	244	23,521
Potential reduction in the number of deaths	*22,758*	*5,188*	*19*	*23,228*

Source of data: Human Mortality Database 2020 (data for the beginning of the year 2020 were estimated by extrapolation from the latest years where data was available); Riffe, Acosta et al. 2020 (numbers of confirmed cases, as well as deaths, are cumulated numbers, the most recent data is used in the analysis, i.e. data from April 23, 2020, for Italy, April 26, 2020, for Germany and Spain, and April 28, 2020, for South Korea); author's calculation.

Supposing that the age-specific rates of cumulative incidence observed in Korea are reachable also by the other countries, it would lead to a massive reduction in the number of confirmed cases – in all the three analyzed European countries more than half a million of cases could be avoided – most of them in Spain. A potential reduction in the number of deaths was calculated using the Korean age-specific rates of cumulative incidence and German age-specific rates of fatality. Because the difference between Korean and German levels of fatality is not crucial, the potential reduction of the number of deaths in South Korea is only marginal (Table 2).

In Germany, the potential reduction of the number of registered deaths reached a value above 5,000. This is the consequence of a model decrease in incidence (calculated using the Korean intensities). Most of the potential reduction in the number of deaths appears in Italy and Spain (around 23,000 in each country, Table 2). In total, in all the analyzed countries more than 51,000 deaths could be avoided if all the countries have reached the incidence levels as is with the South Korean and German rates of fatality. Although reaching such low values may be unattainable for some countries, still, it is clear, that there exists some potential for improvement and reduction in the number of registered cases and deaths.

8. Conclusion

Although most of the studies dealing with the issue of COVID-19 have been from a medical, biological, or epidemiological point of view, currently also the demographic approaches start to be possible as the available database grows. The demographic approach to the analysis enables us to better understand the presented statistics. Within this paper, the age differences in the most important measures were presented. It helps to reveal specific features of particular countries which then affect the overall measures as well as the total registered numbers of confirmed cases of the illness or numbers of deaths from the disease.

In a more detailed analysis, differences in the overall measures among the studied countries were decomposed into the effects of its particular components. It was proved, that the overall level of incidence (crude rate of cumulative incidence) is the consequence of age-specific rates of incidence, the effect of the age structure of the population is smaller. If the age-specific levels of incidence are understood as at least partially impressionable, the overall level of incidence (i.e. also the number of confirmed cases in the population) is potentially influenceable and not solely predetermined by the age structure of the population.

The risk of death among the confirmed cases (age-specific fatality rate) exponentially increases with age. This trend was observed for all the analyzed countries, however, the overall level of fatality was not the same for all of them. In Italy and Spain, the fatality level was much higher in comparison to Germany and Korea, especially at higher ages. Again, the summary measure, the case fatality rate, was decomposed so as it is possible to distinguish the effect of intensity (age-specific fatality rate) and effect of structure (age structure of the confirmed cases). Both these effects played a significant role, the effect of the age structure of the population with confirmed infection was even more important for the overall case fatality rate than the risk of death (age-specific fatality rate) itself. This emphasizes the importance of prevention and (because of the increasing risk of death with age) the necessity to protect seniors or other highly endangered groups.

The crude lethality rate (crude mortality rate because of the COVID-19 illness) was then influenced by two different intensities (age-specific rates of cumulative incidence and fatality) and the age structure of the population. It was proven that the effect of incidence rates was the most important aspect for all the compared countries (again this could be interpreted as the effect of prevention), the impacts of the level of fatality and the age structure were somehow balanced.

Considering that the age structure of the population cannot be changed immediately, the incidence and fatality rates are the (at least partially) controllable components. In the model example, it was shown, how big the differences in those components are, in other words, how significantly the numbers of registered cases of the illness, as well as deaths, could be reduced if the intensities of incidence and fatality were decreased to the lowest observed values in the studied group of countries. Of course, probably not the full reduction (more than half a million registered cases and more than 51,000 deaths in the four analyzed countries) is reachable. However, when dealing with human lives, all the possibilities of prevention, treatment, and reduction of the negative consequences have to be considered. Knowledge of its effects can enable us to better target the treatment or preventive programs.

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ACKNOWLEDGMENTS

Supported by Charles University (UNCE/HUM 018), the author is grateful to both the anonymous reviewers for their valuable comments and recommendations.

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